

Computational Electromagnetics Implementation



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While improvements in commercial computational electromagnetic (CEM) tools are increasing every year, they lag academic advances by ten to twenty years. In addition, the major commercial CEM tools are not general enough to solve the unusual EM problems encountered in LLNL applications, nor are they ported to the latest massively parallel computers in use at LLNL. For these reasons and others, we have created in-house CEM tools such as EMSolve.

Recent projects in CEM have generated significant algorithms and prototype software in the areas of error estimators and improved radiating boundary conditions. Radiating boundary conditions provide a numerical termination of space

for broadband radiation and scattering problems. LLNL's hybrid finite element boundary-element radiating boundary condition offers improved accuracy, as well as reduced sizes for the required finite element mesh. This technology has numerous applications, such as electromagnetic interference, broadband radar, and accelerator wakefield calculations. Error estimators provide a good approximation of the error in the solution of a finite element problem without requiring that the exact solution be known. By visualizing the error estimate throughout the problem, the mesh density or basis function order can be increased in areas with the largest error. This allows convergence to an accurate solution with many fewer mesh refinement iterations,

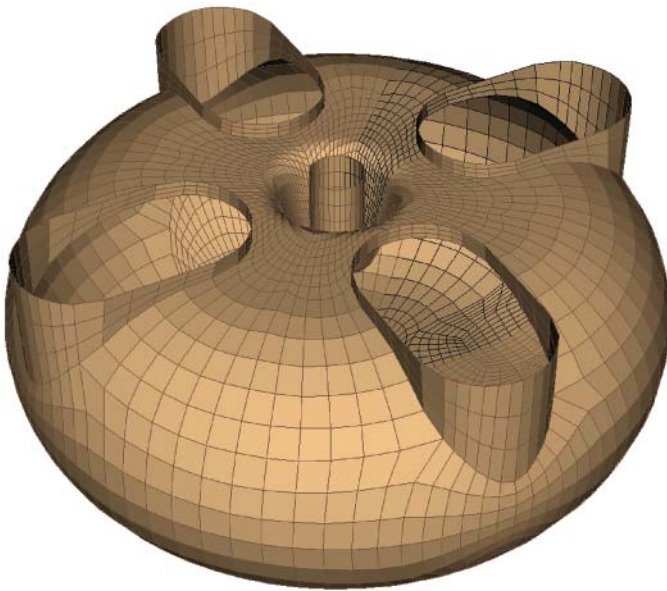


Figure 1. The inner surface of an accelerator induction cell. The round hole in the center is the beam tube. The four oblong holes connect this cell with its neighbor. The section of black mesh lines indicates the cutaway portion shown in Fig. 2.

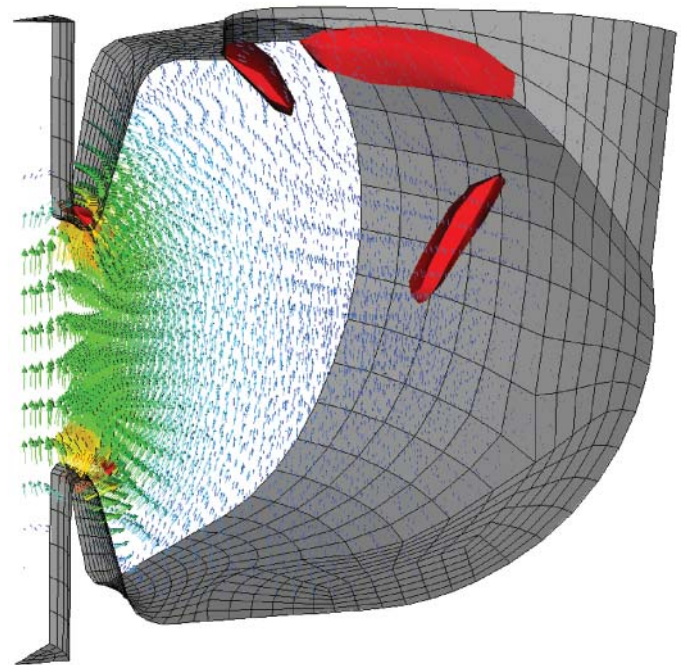


Figure 2. Cutaway image of an induction cell showing the first vector eigenmode of the cavity. The red lobes are areas identified by the residual error estimator as needing refinement. The two lobes near the top are located near a sharp edge in the surface of the mesh and the elements there are relatively coarse, so one would expect that refinement would be necessary. The third lobe was unexpected and on closer inspection it was found to contain poorly formed elements.

and the ability to produce more accurate solutions with less computing power.

This project focuses on fully integrating existing results into EMSolve to be used to solve real problems of interest. The algorithms and software need to be fully combined into the EMSolve framework and physics drivers, tested and verified in the new codes, and documented, so that they can be used easily. In addition, supporting features need to be added to the code to take advantage of the new improvements.

Project Goals

By the end of this project, significant upgrades to EMSolve functionality will be complete. Error estimators will be integrated within the EMSolve drivers for

electromagnetic diffusion, and full-wave time- and frequency-domain EM. A full-wave time-domain radiating boundary condition will be implemented and tested for massively parallel simulations on LLNL's supercomputers. Supporting infrastructure, such as far-field patterns, radar cross-section, and plane-wave scattering formulations will be implemented. In addition, technical and user documentation will be created to assist in applying the new features. The implementation and documentation of these features will allow improved accuracy with fewer simulation iterations for LLNL's CEM work.

Relevance to LLNL Mission

Electromagnetics is a discipline that touches almost every major LLNL program. EMSolve is currently being used to support national security missions, the National Ignition Facility, and the Stockpile Stewardship program. The addition of new features to the EMSolve code, and their documentation, will allow for more accurate, faster results to be produced for these critical projects.

FY2006 Accomplishments and Results

The error estimators were integrated into the EMSolve codes, including time-domain and frequency-domain full-wave

solvers, eigenvalue solvers, and magnetic diffusion solvers. Figures 1 and 2 show sample results generated by the error estimators. The speed of the error estimators was improved by about 60%, and their convergence for multi-material and higher-order problems was tested and verified.

A far-field output was added so that the broadband frequency-domain far-field and radar cross-section could be computed (Fig. 3). The hybrid radiating boundary condition was fully implemented within the EMSolve time-domain full-wave solver (Fig. 4). Its parallel efficiency and accuracy was tested and improved to allow scaling to very large numbers of processors. A scattered-field formulation was implemented to solve plane-wave scattering problems from composite structures.

In addition, the amount of code documentation was increased tremendously, both for the boundary-element and finite element portions of EMSolve. Several other improvements to EMSolve were made, including FORTRAN®-wrapping of the core computational library, consisting of hundreds of routines, improvements to the efficiency of integration rules, accurate memory usage computations, and the ability to define fields on a subset of the overall mesh.

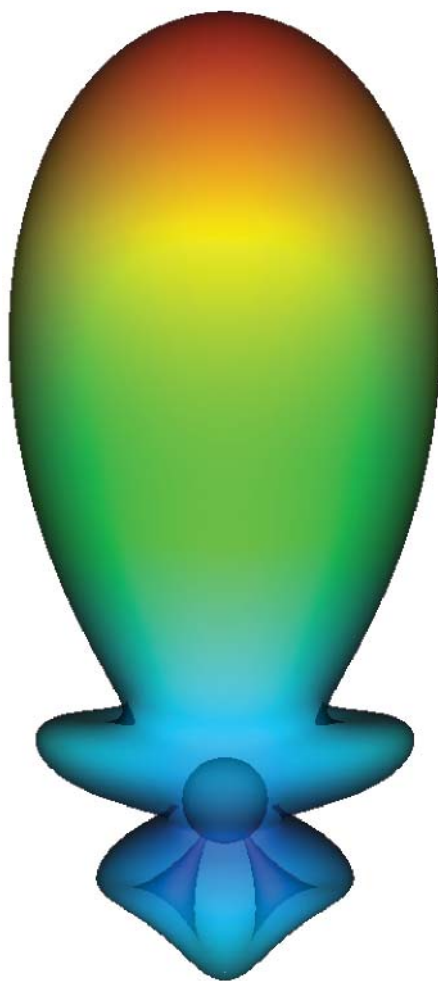


Figure 3. Far-field scattering produced by a four-wavelength dielectric sphere with a relative permittivity of 3.

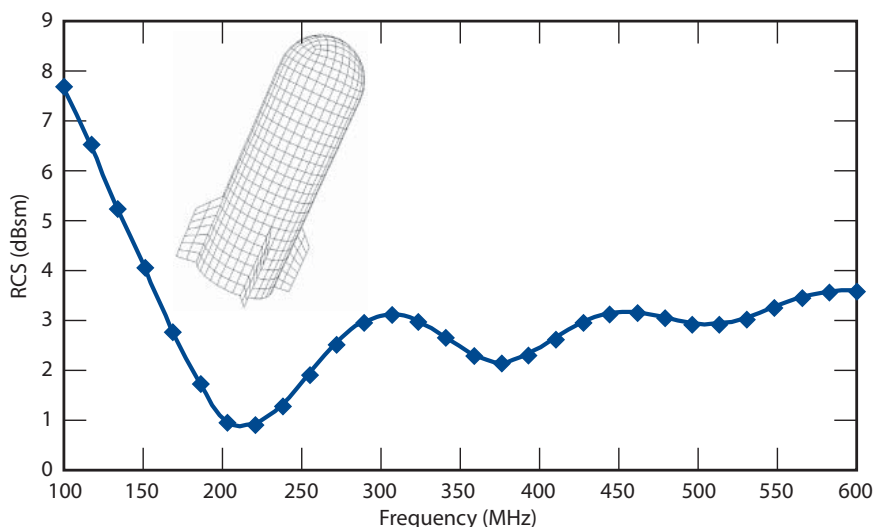


Figure 4. Broadband radar cross-section for a rocket. The radar cross-section determines how visible an object is to radar systems. The monostatic radar cross-section for a broadside pulse polarized along the rocket axis using the hybrid radiating boundary condition is displayed.